2018 UPDATED HORSE MACKEREL ASSESSMENTS

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SUMMARY

The assessments for the two hypotheses (reduced catchability and a one-off additional mortality event) for the recent reduced *Desert Diamond* catch rate are updated to take one further year's data into account. The 2017 CPUE somewhat increased above its 2016 value, and now almost returned to the values typical before the 2014 low. If the same basis as in the recent past is used to make management recommendations with an unchanged effort limitation, the total allowable midwater catch would be set at 23 851 MT. However the assessment results, given this data update, are suggestive of the catchability hypothesis now being more plausible than the additional mortality hypothesis. This in turn suggests that consideration should be given to some increase in the cap on effort, which would lead to a concomitant increase in the midwater TAC.

INTRODUCTION

This document reports the 2018 updated horse mackerel assessments. The input data which include updates to the catch series and CPUE series are reported in Fairweather and Singh (2018), and in Singh (2018).

OPERATING MODELS

FISHERIES/2017/SEP/SWG-DM/31 provided results for an initial set of assessment models for Horse Mackerel for 2017 taking the then most recent data (to 2017 into account. The SWG recommended that further assessment variants models be run that omitted the 2015 *Desert Diamond* (DD) CPUE value. Two main model variants were recommended – these two models explain the very low 2014 to 2016 observed CPUE *Desert Diamond* values in very different ways. The inclusion of the Dual Rights vessels' (DR) CPUE series was also recommended for examination - see FISHERIES/2017/SEP/SWG-DM/43. Note that all these models omit the DD 2015 CPUE value in the model fitting process. In the light of these suggestions made in 2017, the set of 2018 updated assessment models presented here are as follows. Note that Models 3a and 3a_DR are slightly modified from the formulation used a year previously in that the q values are now assumed to change linearly between 2014 and 2017.

Model 3a: The DD 2015 CPUE value is excluded from the model fit.

$q = q_1$ for years up to and including 2013,

$q = q_2$ for year 2014,

$q = q_3$ for year 2017 and for projections (and is limited to be $\leq q_1$),

q is linearly interpolated between q_2 (in 2014) and q_3 (in 2017) to obtain the q values for 2015 and 2016 (although note that the 2015 CPUE value is omitted in the model fit).

This model thus assumes that the recent low CPUE values could be a result of reduced fishing catchability.

Model 5a: The DD 2015 CPUE value is excluded from the model fit.

An extra mortality event occurs at the start of 2014 (numbers-at-age in 2014 are all reduced by an estimated additional proportion M^{extra}). This extra mortality is a one-off event.

Model 3a_DR: Model 3a but includes the Dual Rights vessels' CPUE in the model fit.

Model 5a_DR: Model 5a but includes the Dual Rights vessels' CPUE in the model fit.

PROJECTIONS

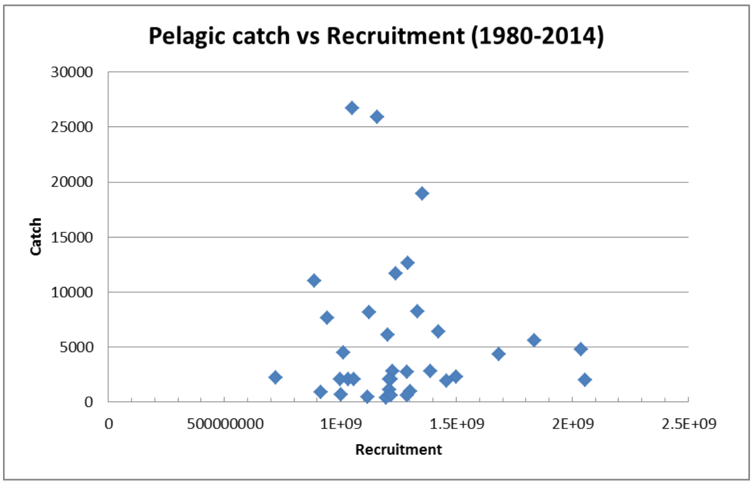
OMPs explored last year (2017) to provide management advice

This document reports the results of horse mackerel projections under the alternative management options (termed OMPs). These projections take account of the range of uncertainties about whether the recent downturn in the midwater CPUE reflects a temporary catchability reduction or a one-off additional mortality. For each projection scenario, the resource is projected ahead for 10 years and the projections are repeated 1000 times with noise added to the future recruitment and incorporating uncertainty about future CPUE estimates.

The rules (OMPs) to compute future simulated catches under various management approaches are set out below.

1) Pelagic bycatches

The Figure below plots pelagic bycatches (in MT) against annual horse mackerel recruitment.



- Note that there is no clear relationship between pelagic bycatches and recruitment.
- Hence future pelagic bycatches are set by drawing at random with replacement from the set of pelagic bycatches for the period 2000-2015, except that a value in excess of $PUCL_{y+1}$ below is reduced to $PUCL_{y+1}$, where:

$$PUCL_{y+1} = 12\,000 - C_y^{pel} - C_{y-1}^{pel}. \quad \text{(Units: MT.)}$$

Note 12 000 (previously called $PULC_3$) is the total amount in MT that may be caught over a three-year period (see FISHERIES/2015/Mar/SWG-DEM/03).

2) Incidental trawl/Demersal bycatches – constant proportion of HM biomass

As recommended in FISHERIES/2016/OCT/SWG-DEM/79, the average reported incidental bycatches for the period 2000-2013 (now updated to 2015) should be considered in the averaging in order to produce a more representative $\bar{F}_{trawl}$ exploitation rate value. Table 1 below reports these demersal bycatches, Model 3a and Model 5a estimated horse mackerel biomass values, and the resultant exploitation proportion F=C/B for each model. The F values were averaged over the two models, and the median and upper 95th percentile over the years calculated (assuming a normal distribution). It was agreed that the upper 95th percentile (to allow for catchability fluctuations) of the 2000-2015 F values (which turns out to be 0.0294) would be used as the $\bar{F}_{trawl}$ value in future equations to calculate the future demersal bycatches, i.e.:

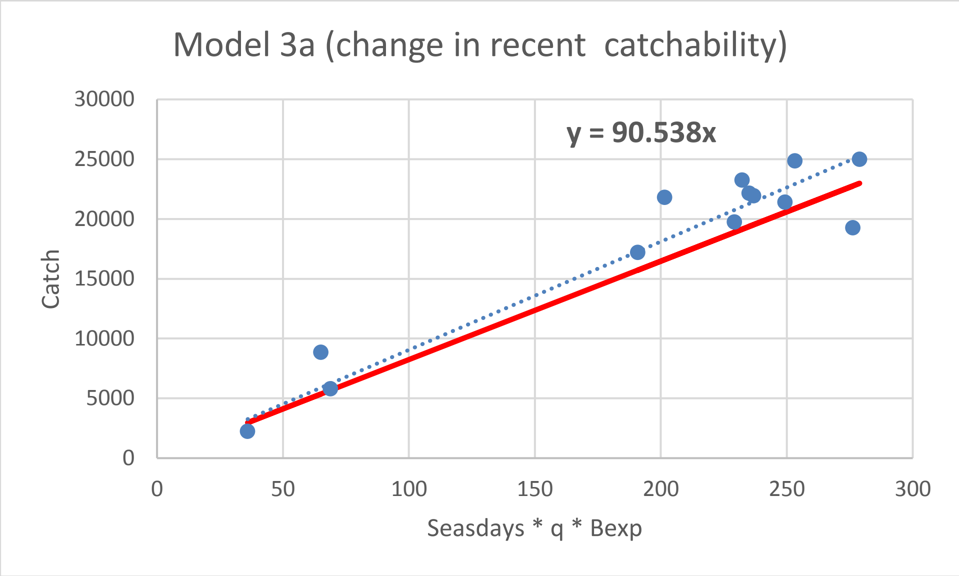
$$\text{Future demersal bycatches} = \bar{F}_{trawl} * B_{exp}^{dem}$$

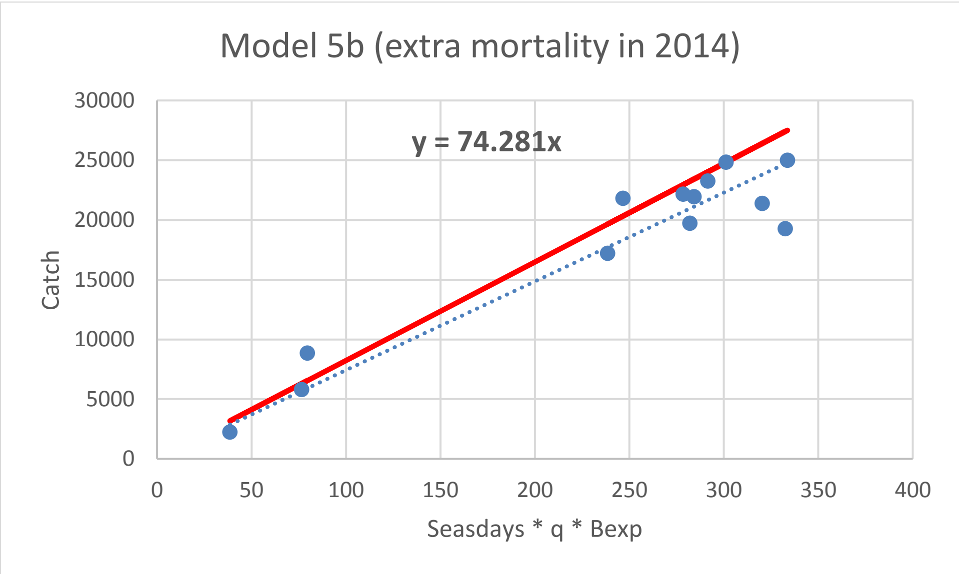
3) Midwater directed catches

The two plots below show the observed (circles) midwater catches plotted against:

$$q * B_{exp}^{mid} * Seadays\_used.$$

The top plot is for Model 3a (which assumes that catchability has been reduced in recent years) and the bottom plot if for Model 5a (which assumes an extra mortality in 2014)





A linear regression through the origin of the form shown below was fitted to these data:

$$C = k.(q * B_{exp}^{mid} * Seadays_{used})$$

These regressions are shown as dotted lines on each plot with the regression equation shown on each plot. A single "regression" is needed to project, so the way forward adopted was to simply take the average of the two regressions – these are shown as the red solid lines on each plot. The averaged regression is:

$$C = k.(q * B_{exp}^{mid} * Seadays_{used})$$

where $\boldsymbol{k} = \mathbf{82.41}$.

The average standard deviation of the residuals about the regression line, σ , is 4943 MT.

The midwater catch in each future year is then determined as follows.

i) An Initial catch (C_1) set at 30 773 MT (as calculated by the Furman OMP for 2018 – see the Appendix).

ii) A Secondary (C_2) catch is calculated related to the limit on *Seadays*:

$$C_2 = k\left(q * B_{exp}^{mid} * Seaday_{limit}\right) + error$$

where for each year of each replicate projection the error is generated from $error \sim N(0, \sigma^2)$,

and where $q * B_{exp}^{mid}$ are the future midwater CPUE values, and $Seaday_{limit}$ value is fixed at 200, 250, 300 or 388.

The final midwater catch simulated is the **lesser** of C_1 and C_2.

Furthermore, a lower bound on midwater catch of 2000 MT is imposed.

OMPs explored (similar to 2017, but with larger Seaday limits for reasons discussed below)

1) Midwater initial catch C_1 = 30 773 MT (as indicated by the Furman OMP for 2018 – see FISHERIES/2016/OCT/SWG-DEM/66). The Appendix shows the workings for this amount.
   Midwater catch lower bound 2000 MT
   $Seaday_{limit}$ = 300,388, 430 or 460 days
2) C_1 = 30773 MT; no Seaday restriction; midwater catch lower bound 2000 MT
3) C_1 = 20 000 Mt; no Seaday restriction; midwater catch lower bound 2000 MT

RESULTS

Operating Models

Table 1 reports the results of the operating (assessment) models described above.

Figure 1a compares the model fits to the DD CPUE data, and Figure 1b compares the Model 3a_DR and Model 5a_DR fits to the Dual Rights vessels' CPUE data. Figure 2 plots the estimated spawning biomass trajectories in absolute terms (top) and as proportions of their unexploited equilibrium levels (bottom). Figure 3 compares the stock recruit residuals between Model 3a and Model 5a.

Projections

Figures 4a and d plot various model projections for all seven OMPs explored, and for all four OMs (Model 3a OM (Figure 4ai and ii), Model 5a (Figure 4b), Model 3a_DR (Figure 4c) and Model5a_DR (Figure 4d). Each figure plots the median and 5th %ile of the Bsp/K trends, the CPUE trends, and the midwater catches. Figure 4e plots the total catches (midwater and both sources of bycatches) for the projections; the three-yearly cycle in these catches arises from the form of the PUCL rule for pelagic fishery bycatches.

DISCUSSION

Operating Models

Model 3a (fishing selectivity change scenario) produces the best fit to the recent low 2014 and 2016 CPUE values, and Model 3a fit is better than the Model 5a fit in terms of its total –lnL value (Table 2). This though must be interpreted in the context that Model 3a has effectively more estimable parameters than Model 5a. The implications for current spawning stock size are very different for the Model 3a and Model5a, with Model 3a estimating current (2018) spawning biomass to be 59% of the carrying capacity, whereas Model 5a estimates this value to be some 38% only. Adding Dual Rights vessels' CPUE data to the model fits (Model 3a_DR and Model 5a_DR) produces a slightly more optimistic current biomass estimate for Model 3a, and more so for Model 5a (Table 2).

Projections

For all of the four OM models considered, under the constant catch scenarios for the directed midwater fishery, the spawning biomass lower 5th %ile envelope keeps decreasing in the medium-term future (Figures 4a-d).

Under the more optimistic scenario (Model 3a – a temporary reduction in catchability which then returns to normal), the expected midwater trawl catch for 2019 under 388 *Desert Diamond* equivalent days at sea would be 23 851 MT (see Figure 4a(i)). This is equivalent to the basis used in 2016 and 2017 to set the TAC for this midwater component of the fishery for 2017 and 2018 respectively. Accordingly, if the same approach used for recommending limitations on the midwater fishery for 2017 and 2018 is adopted for 2019, those limitations would be a midwater TAC for 2019 of 23 851 MT and an unchanged effort restriction for directed midwater trawl fishing of 388 *Desert Diamond* equivalent sea days.

However, the continued increase in the *Desert Diamond* CPUE leads to a greater difficulty for the model based on additional mortality to fit these data compared to that based on reduced catchability (now returned to normal (see Table 2 and Figure 1a). This suggests that lower plausibility should now be accorded to the former relative to the latter hypothesis. In turn, that opens the door to considering a possible increase in the number of Seadays. In such circumstances, the midwater TAC value would increase to 26 004 MT for 430 Seadays, and to 27 670 MT for 460 Seadays.

References

Fairweather, T.P and Singh, L. 2018. Total horse mackerel catch by various fleets and dual-rights nominal horse mackerel CPUE – updated time series. FISHERIES/2018/OCT/SWG-DEM/52.

Singh, L. 2018. The 2018 updated horse mackerel standardised CPUE. FISHERIES/2018/OCT/SWG-DEM/53.

Table 1: Demersal bycatches, model estimated horse mackerel biomass values and resultant exploitation proportions F=C/B (caused by the incidental demersal trawl catches) for both Model 3a and Model 5a. Average F provides the annual average of the Model 3a and the Model 5a F estimates. Biomass units are MT.

	Demersal bycatch	Model 3a horse mackerel biomass	Model 3a F	Model 5a horse mackerel biomass	Model 5a F	Average F
2000	9229	285655	0.0323	292591	0.0315	0.0319
2001	8814	299388	0.0294	318436	0.0277	0.0286
2002	4863	312522	0.0156	343247	0.0142	0.0149
2003	3562	309911	0.0115	344889	0.0103	0.0109
2004	4933	279457	0.0177	285853	0.0173	0.0175
2005	5280	308627	0.0171	302242	0.0175	0.0173
2006	4133	319777	0.0129	305757	0.0135	0.0132
2007	4812	320744	0.0150	324871	0.0148	0.0149
2008	4449	373260	0.0119	390428	0.0114	0.0117
2009	4129	397915	0.0104	427116	0.0097	0.0100
2010	5596	380209	0.0147	413104	0.0135	0.0141
2011	5228	345094	0.0151	375526	0.0139	0.0145
2012	4941	324664	0.0152	355969	0.0139	0.0145
2013	2695	330527	0.0082	378407	0.0071	0.0076
2014	3087	303632	0.0102	193586	0.0159	0.0131
2015	4747	258939	0.0183	188063	0.0252	0.0218
					median	0.0145
					upper 95%ile	**0.0294**

Table 2: Summary of results for four different OMs. All variants fix q_{aut} = 0.75 and *h* = 0.75. “SR” and “CAL” refer to stock-recruitment and catch-at-length contributions respectively. Biomass units are thousand MT.

	Model 3a $q = q_2$ for 2014 q_3 for 2017	Model 5a Extra proportion M^{extra} die at start of 2014	Model 3a_DR $q = q_2$ for 2014 q_3 for 2017 Fit to DR CPUE	Model 5a_DR Extra proportion M^{extra} die at start of 2014 Fit to DR CPUE
-ln L :Total	-236.67	-227.27	-141.45	-232.80
-ln L :Spr survey	0.496	1.012	0.873	1.409
-ln L :Aut survey	-10.17	-5.614	-9.60	-7.70
-ln L :CPUE	-11.37	-5.647	-9.74	-0.77
-lnL Dual Rights	-	-	-5.55	-7.19
-ln L :CAL Spr survey	-44.94	-45.71	-46.25	-46.99
-ln L :CAL Aut survey	-88.07	-87.01	-88.41	-88.29
-ln L :CAL commercial	-198.55	-65.80	-65.72	-66.11
-ln L :SR residuals	-17.07	-18.50	-17.05	-17.05
K^{sp} (KT)	792	852	793	820
B^{sp}_{2018} (KT)	**466**	**326**	**491**	**434**
$MSYL^{sp}$ (KT)	196	211	197	203
MSY (KT)	59	63	59	62
B^{sp}_{2018}/K^{sp}	**0.589**	**0.382**	**0.618**	**0.530**
$B^{sp}_{2018}/MSYL^{sp}$	2.378	1.545	2.492	2.138
$MSYL^{sp}/K^{sp}$	0.247	0.247	0.248	0.248
q: Spr survey	0.796	0.726	0.786	0.796
q: CPUE (x10^{-6})	1.627	1.732	1.613	1.672
q_2 (applies to 2014)	$0.180*q_{CPUE}$	-	$0.172*q_{CPUE}$	-
q_3 (applies to 2017)	$1.000*q_{CPUE}$	-	$1.000*q_{CPUE}$	-
M^{extra} (once-off extra proportion die in 2014)	-	0.513	-	0.724
	Xhm18a.tpl	Xhm186.tpl	M3dr18.tp	M5dr18.tpl

Figure 1a: Comparison between the operating model fits to the *Desert Diamond* (DD) CPUE values.

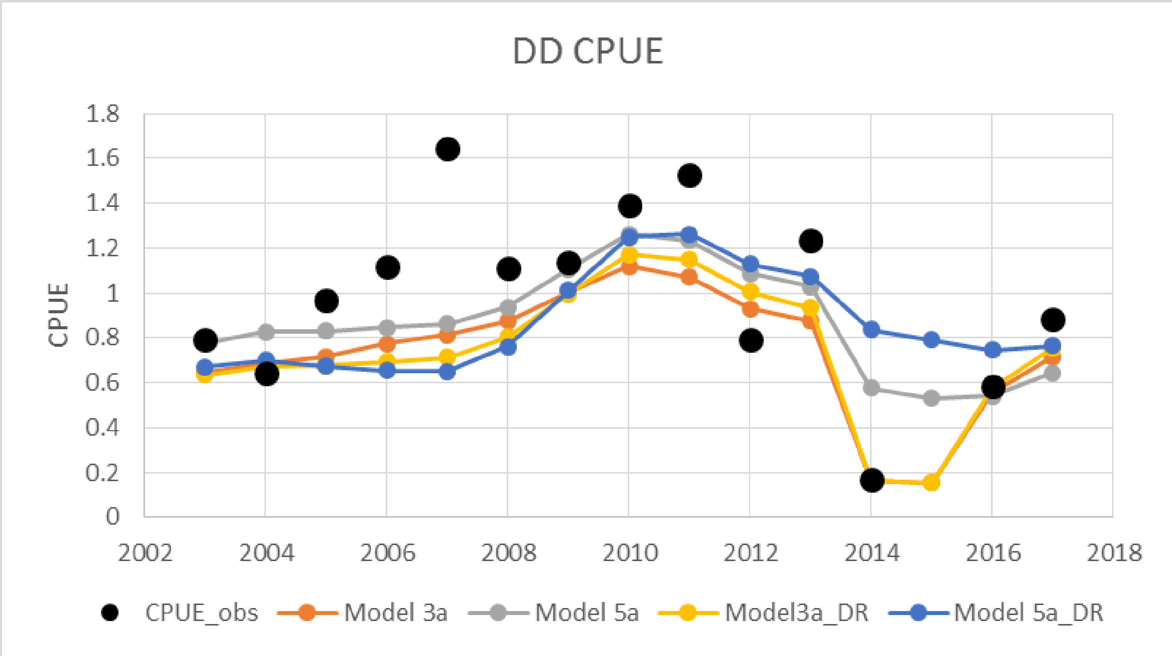


Figure 1b: Comparison between Model 3a_DR and Model 5a_DR to the Dual Rights vessels' CPUE values.

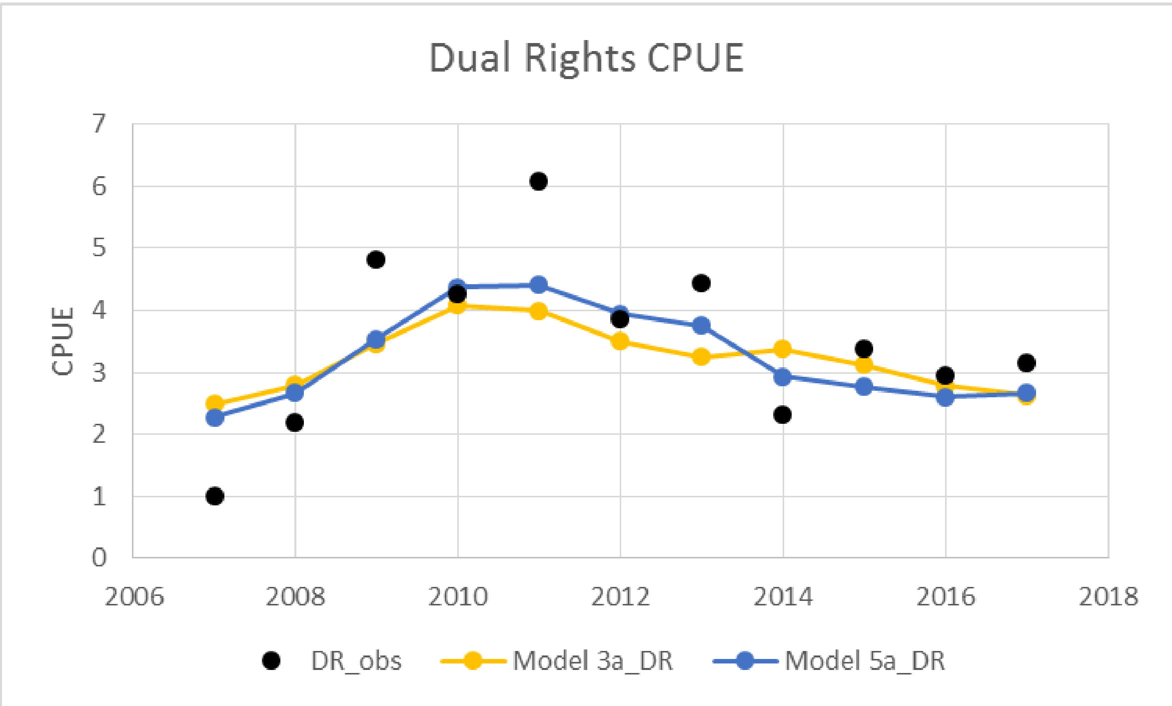


Figure 2: Operating model Bsp and Bsp/Ksp estimates.

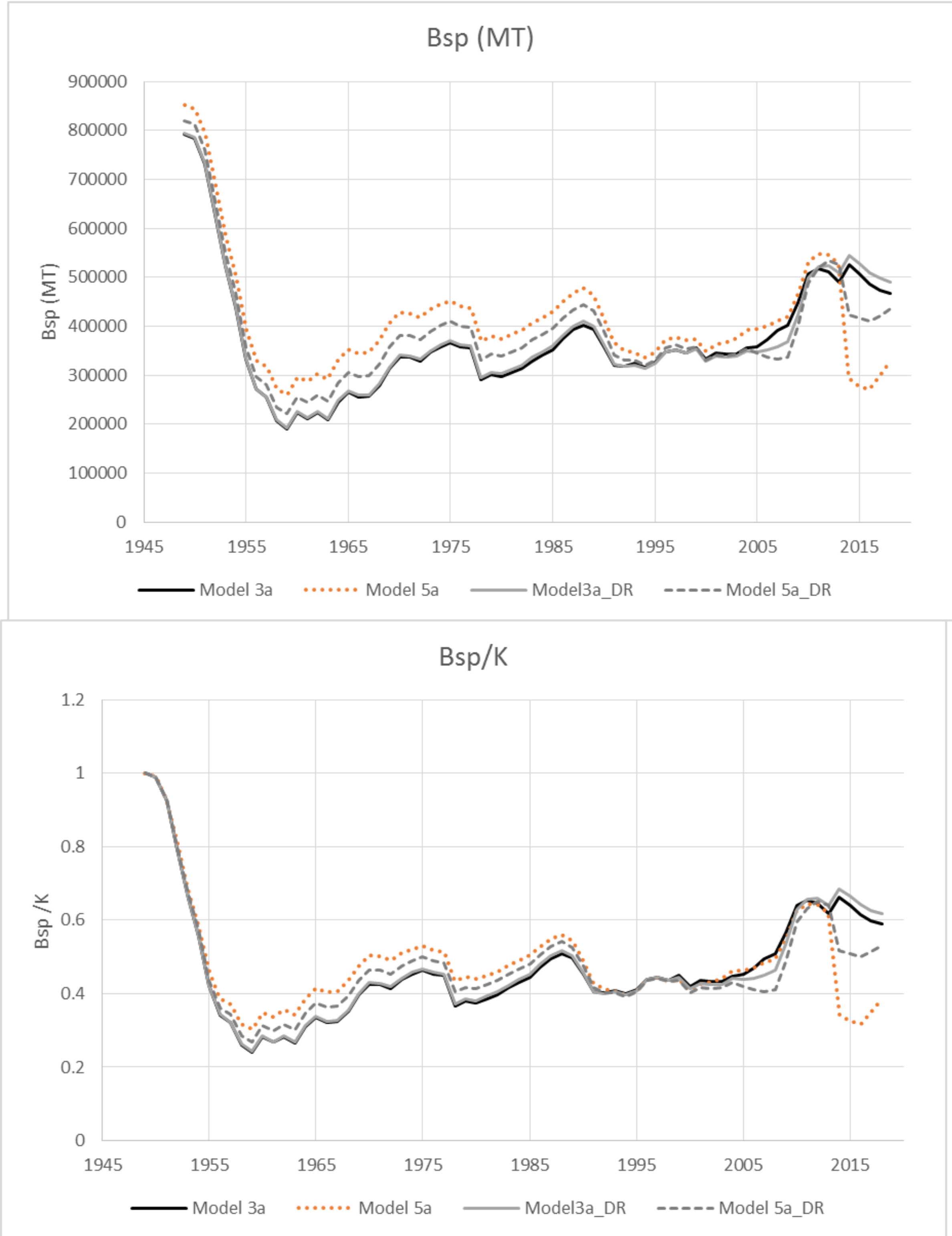


Figure 3: Stock recruit residuals for Model 3a and Model 5a.

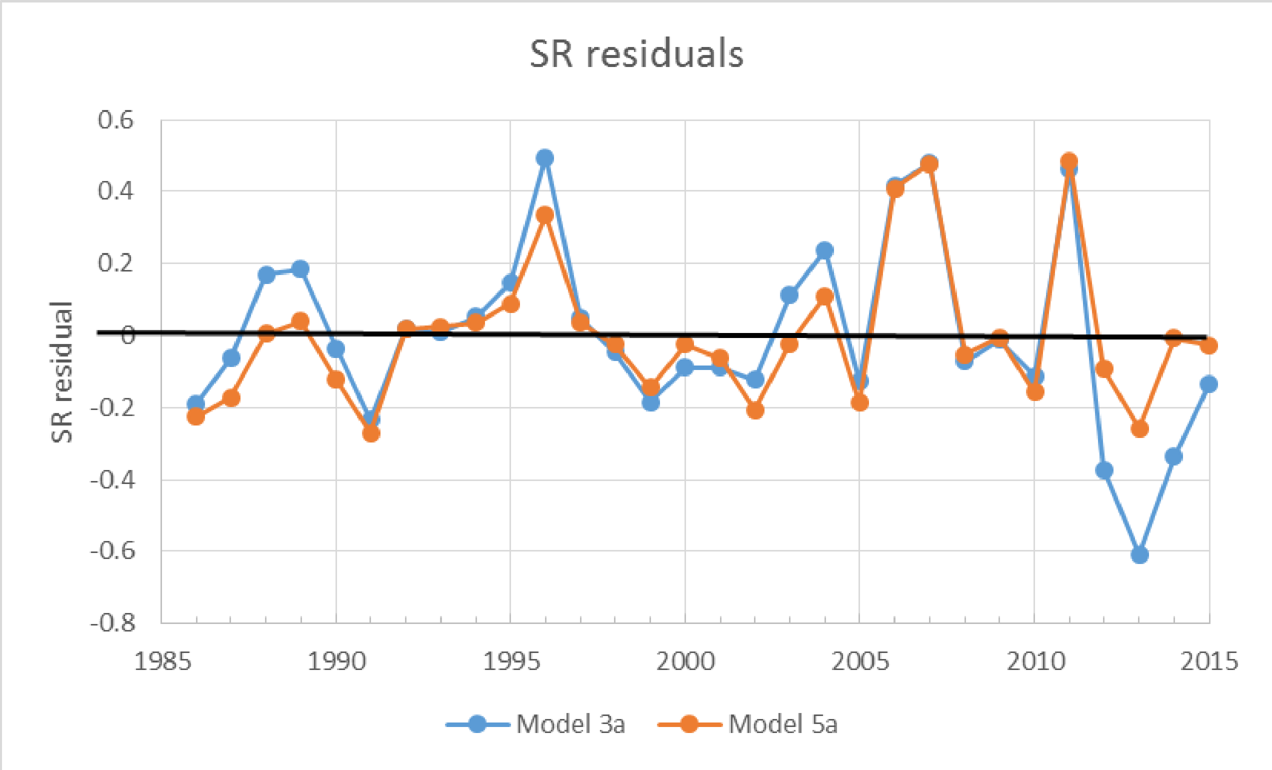


Figure 4a(i): Model 3a projections– results are shown for all six OMPs. Catches given here and in the Figures following are in MT.

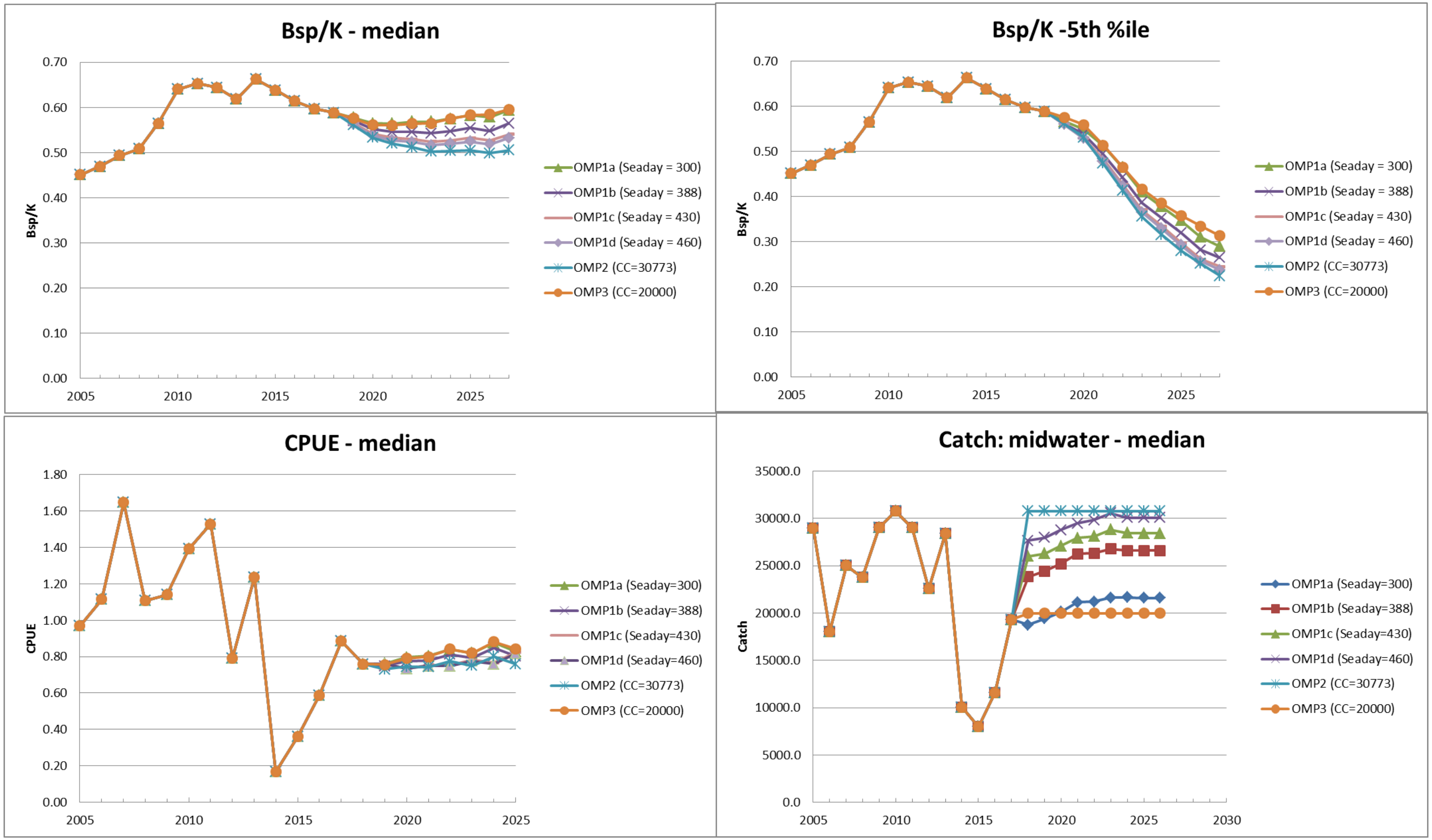


Figure 4a(ii): Model 3a pelagic, demersal, midwater and total catch projections– results are shown for all six OMPs. Vertical arrows show start of projection.

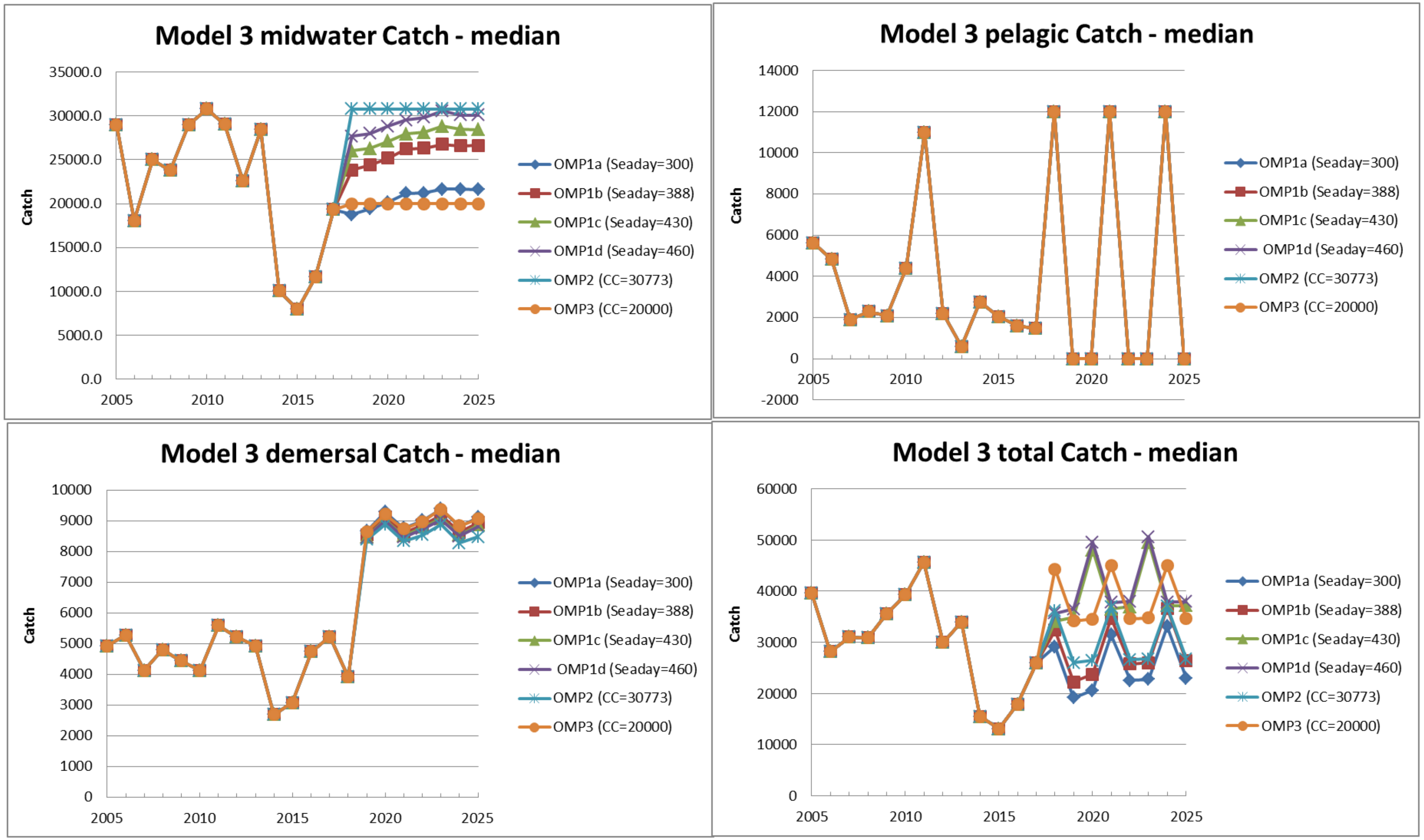


Figure 4b: Model 5a projections – results are shown for all six OMPs.

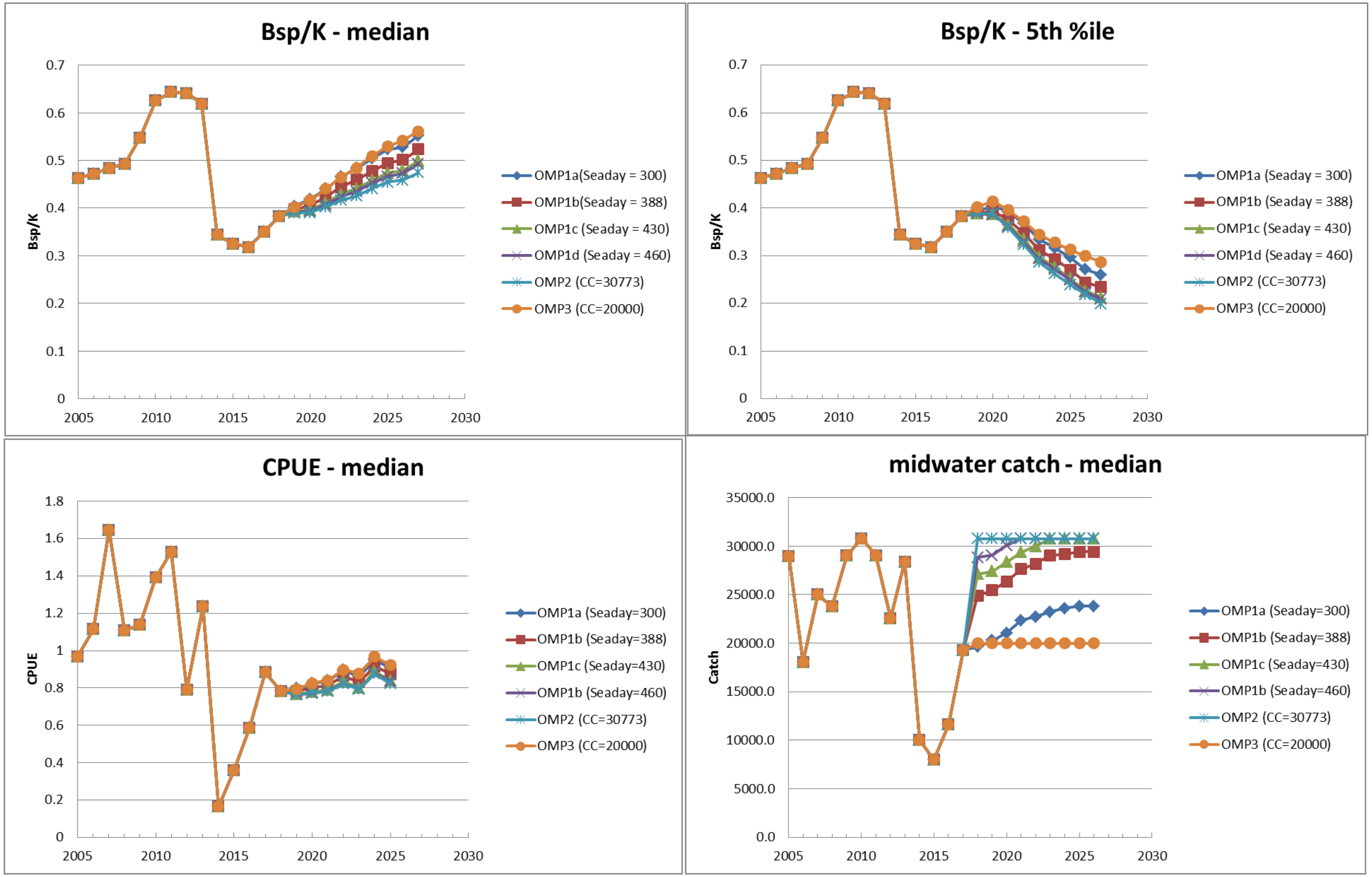


Figure 4c: Model3a_DR projections– results are shown for all six OMPs.

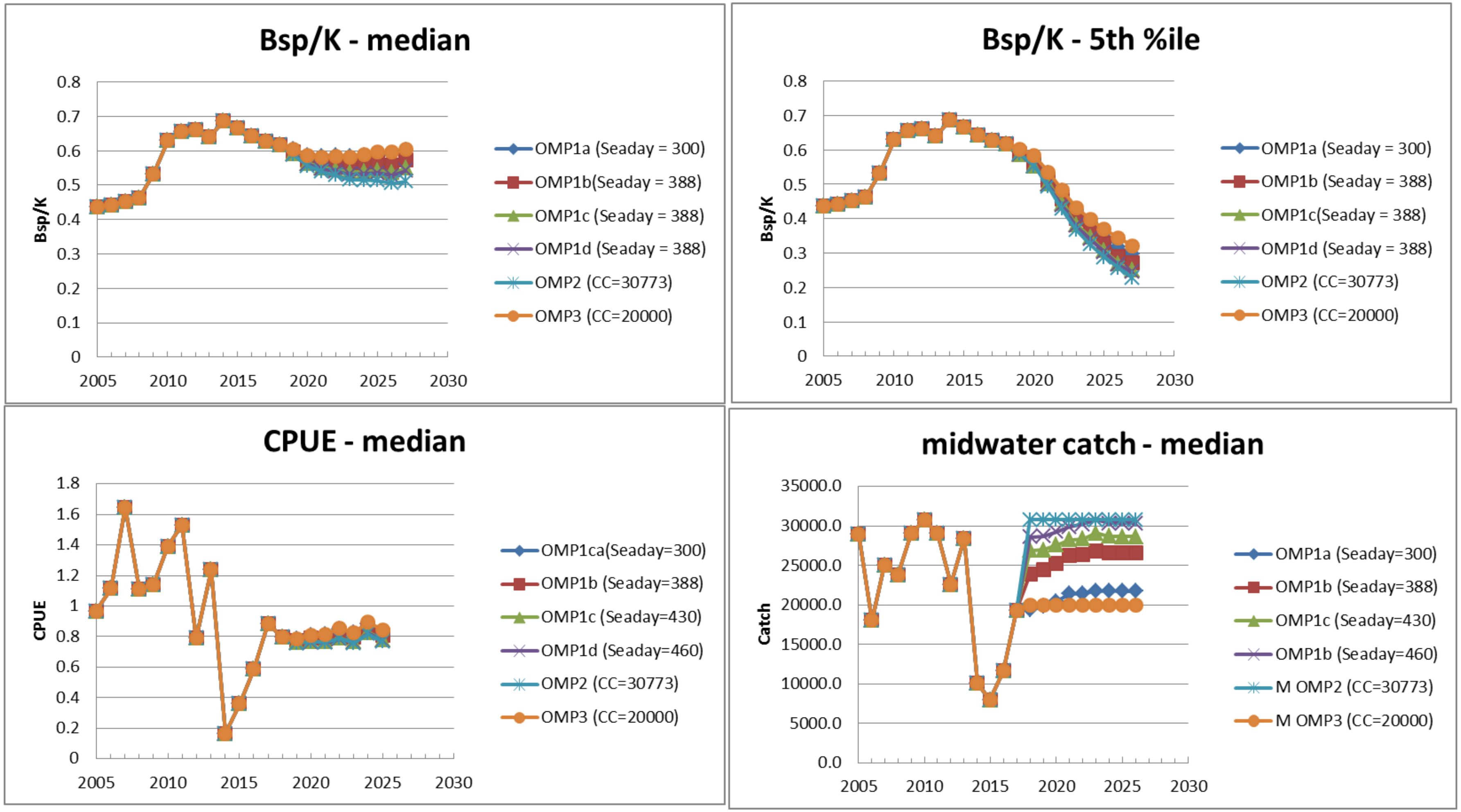


Figure 4d: Model5a_DR projections– results are shown for all seven OMPs.

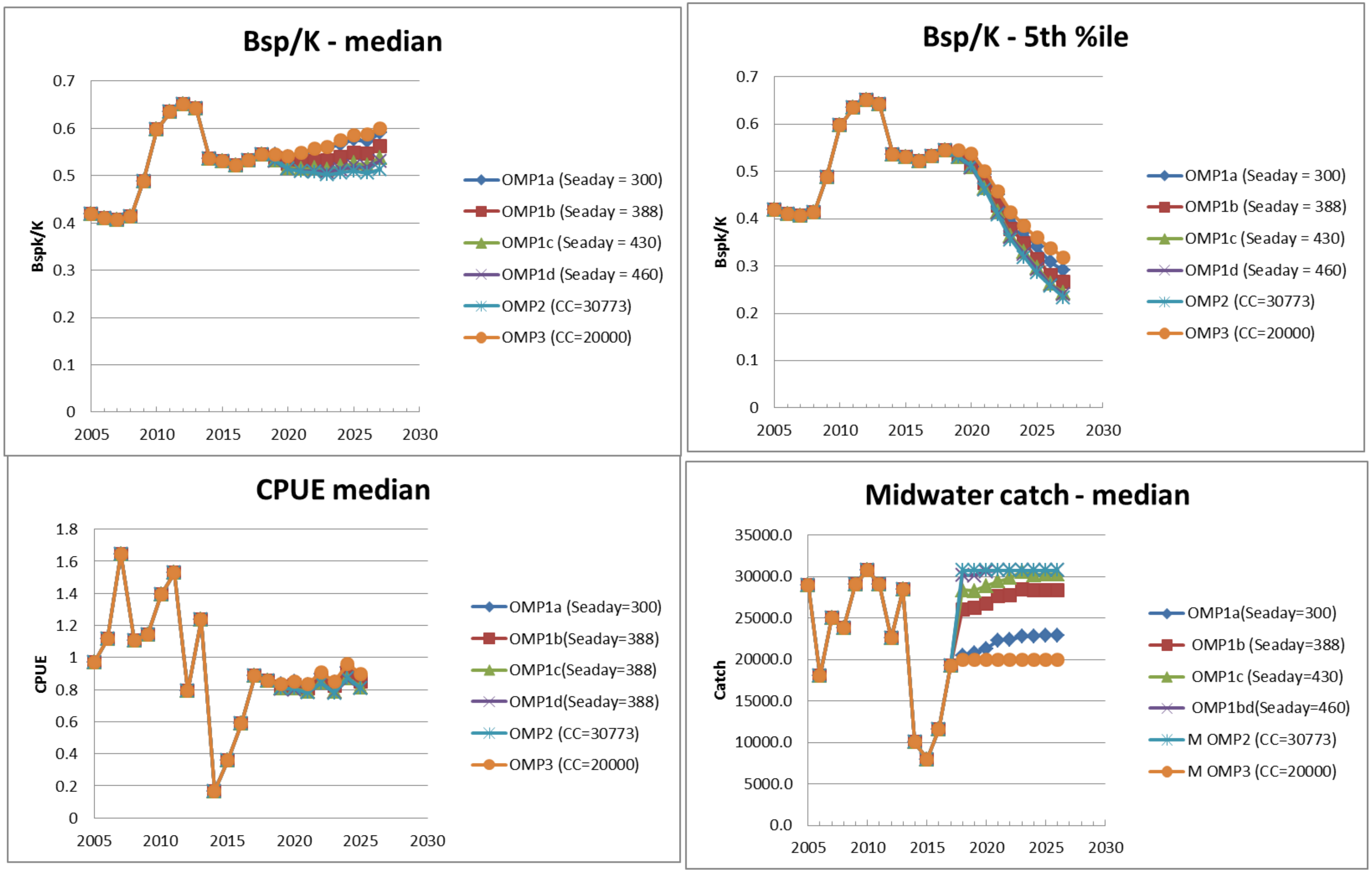
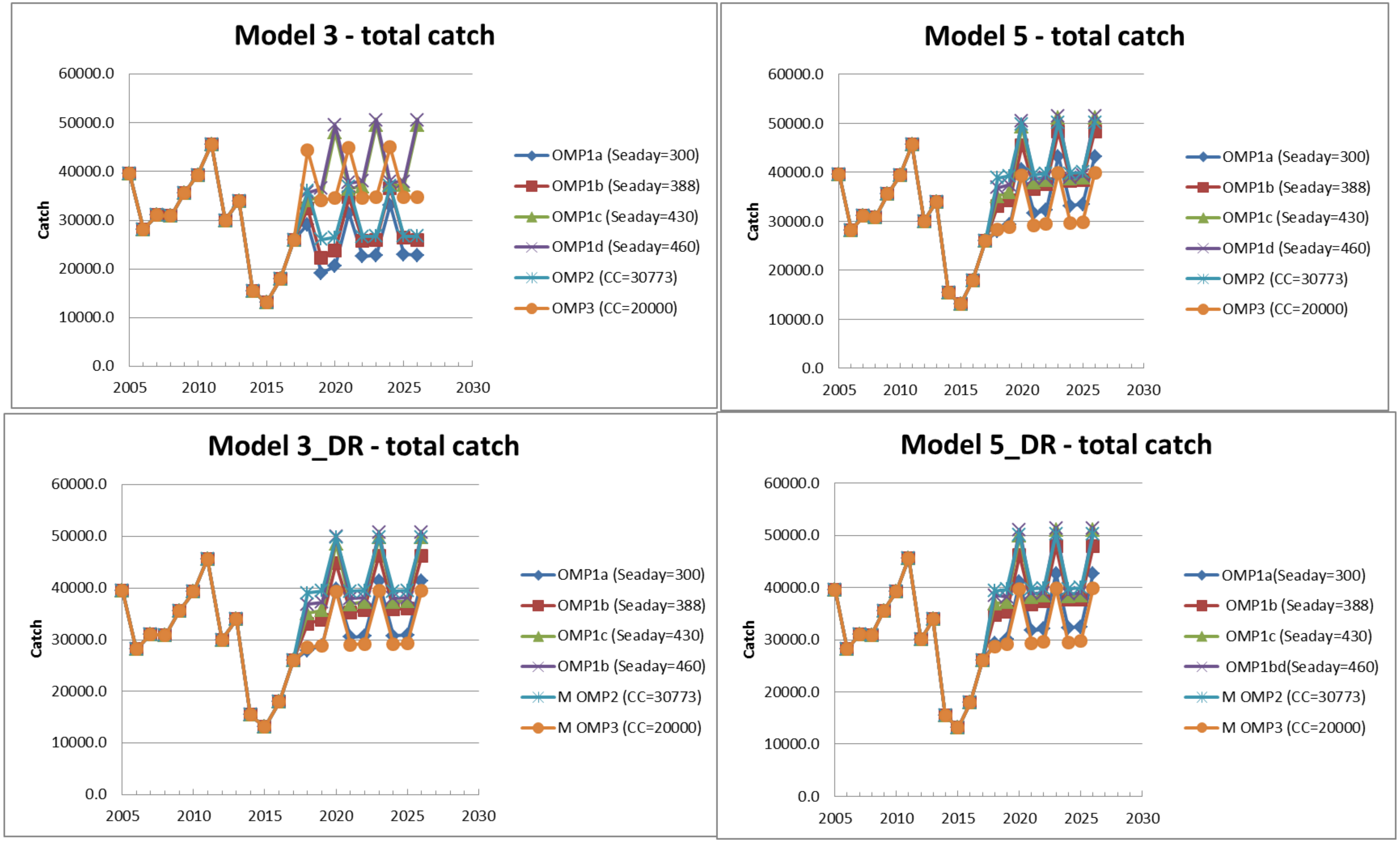


Figure 4e: Total catch (midwater and both pelagic and demersal bycatches) projections for the four OMs - results are shown for all six OMPs.



Appendix: TAC for the midwater fleet for 2018 based on the Furman OMP

The Furman OMP (FISHERIES/2016/OCT/SWG-DEM/66) is used in conjunction with the most recent CPUE series (FISHERIES/2018/OCT/SWG-DEM/53) to provide a Horse Mackerel TAC recommendation for the midwater sector.

The Catch control rules for the midwater catches are as follows:

$$TAC_{y+1} = \Delta_y \, TAC_y$$

$$\Delta_y = \begin{cases} 1 - X_{decr} & \text{for} \quad I_y < I_{decr} \\ 1 - X_{decr} + \dfrac{X_{incr} + X_{decr}}{I_{incr} - I_{decr}}\left(I_y - I_{decr}\right) & \text{for} \quad I_{decr} \leq I_y < I_{incr} \\ 1 + X_{incr} & \text{for} \quad I_y \geq I_{incr} \end{cases}$$

I_y is related to a weighted average of the last three years of CPUE data, e.g.:

$$I_{2018} = \frac{1/3 \sum_{2014,2016,2017} CPUE_y}{1/7 \sum_{2003}^{2009} CPUE_y}$$

$$= \frac{0.5459}{1.0594}$$

$$= 0.515$$

Thus as $I_{2018} < I_{decr}$ i.e. (0.505 < 0.84)

$$\Delta_y = 1 - X_{decr} = 1 - 0.15 = 0.85$$

Therefore

$$TAC_{2018} = 0.85 \, TAC_y = 0.85 \, (36204) = 30773 \text{ MT}$$

I_{inc} and I_{dec} values as calculated by Furman from the revised midwater MP (using the revised CPUE series in 2014):

I_{decr}	**0.85**
I_{inc}	**1.01**
X_{inc}	**0.1**
X_{decr}	**0.15**